

# SCIENCE FOR GLASS PRODUCTION

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## METHODS FOR IMPROVING OPTICAL PARAMETERS OF FLOAT GLASS (A REVIEW)

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The effect of the processes of discharge and spreading of glass melt in the melt tank on optical parameters of float glass is considered. The existent design and technological solutions for leveling the temperature gradient in melted glass flow, which is one of the main factors in the formation of optical distortions, are described.

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The important quality parameters of float glass, which determine its consumer and service properties, include optical parameters that are usually characterized by the optical distortion angle Zebra. Researchers of the float-glass process believe that one of the main factors degrading the optical parameters of float glass is the heterogeneity and deformation of glass layers [1–4].

Prerequisites for the formation of heterogeneous layers (lamination) are developed at various technological stages of glass production starting with the processes of batch preparation and charging of the glass-melting furnace and ending with the molding processes in the melting tank.

The formation of heterogeneous layers and their deformation at the discharge and spreading stages are inevitable for the following reasons. At this point, a temperature gradient always exists in the cross-section of the glass melt flow, when the temperature in the center of the flow is higher than at the edges. This circumstance in the discharge zone is caused by heat losses via the lateral walls of the discharging chute, and in the spreading zone is due to more intense chilling of the edges of the glass band compared to its central part. Apart from the cross-section gradient, a temperature gradient exists across the glass melt thickness due to unequal chilling of the central and the surface layers, which is due to different heat-transfer coefficients of glass melt, tin, and refractories and to the processes of convection and radiation.

As in any viscous flow [5], a velocity gradient arises in the glass flow due to the contact (friction) of the glass layers against the discharge chute walls and the working surface of the restrictors. Furthermore, as a consequence of the cross-section temperature gradient of the glass melt, the glass lay-

ers have a different viscosity and, accordingly, different velocities with respect to each other. The central flows move at a higher velocity than the edge flows, which causes an additional increase in the velocity gradient [6]. All this leads to the formation of a stratified heterogeneous structure of glass.

As for the layer deformation, it can emerge when the glass melt via a slanting chute is discharged onto melted tin if the chute tip is incorrectly positioned with respect to the level of the tin and the back wetted restrictor, or in lateral spreading of the glass melt in the melt tank.

An analysis of the patent and technical literature indicates continuous research in the field of improving the discharge and spreading segments, since the requirements imposed on the float-glass quality are constantly growing. Numerous techniques have been developed for setting conditions in the discharge and spreading zones that would ensure improvement of the optical parameters of glass. These techniques are mainly intended to decrease the temperature gradient across the melt flow in the discharge and spreading zones.

First, they include different variants of heating glass melt in the discharge and spreading zones, which by means of introducing additional heat or redistributing heat compensate the chilling of the glass melt in the lateral flows or in a pocket and create conditions for the formation of a homogeneous structure of glass layers.

One of the methods proposes a proportioning valve with heating elements for heating glass melt in discharge (Gr. Britain patent No. 1169313). The possibility of differentiated heating across the width of the valve makes it possible to smooth over the temperature gradient and to ensure a uniform temperature in the cross-lateral direction. The literature

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also describes a special heater located under the chute tip along the back wetted restrictor, which does not contact the glass melt (U.S. patent No. 3508902).

Direct heating of glass melt by electric current has been proposed as well (Gr. Britain patents Nos. 1124624 and 1138747). Some refractory materials, especially fused refractories, can be used as electric resistance and current can pass through them. In this way heat is transferred from the heated refractory surface to the glass melt and decreases the melt viscosity, thus intensifying the glass melt flow in the pocket along the back wetted restrictor. In the described variants, the back wetted restrictor acts as an electrode and the second electrode is a graphite bar incorporated in the bottom of the melt tank.

Several techniques are described for the spreading zone. Thus, heating of glass melt in the spreading zone can be implemented using electrodes incorporated into the restrictors (Gr. Britain patent No. 1112071). The controlled heating of the restrictor walls facilitates thermal homogeneity in the glass melt moving between the restrictors, as a consequence of which the glass flow at the exit from the restrictors has a uniform temperature across its section. Furthermore, heating of the restrictors makes it possible to lower the viscosity in the edge parts of the glass flow and to intensify their velocity, which facilitates uniform motion of the glass melt in the restrictor zone and levels the velocity gradient.

To reduce the temperature gradient in the glass band, it is also possible to use special lateral heaters located in the spreading zone directly above the edge parts of the glass band (U.S. patent No. 3533773).

A variant of using a radiation screen (a reflector) located above the glass band in the spreading zone is described (U.S. patent No. 3928010). The screen reflects the heat radiated by the glass arriving on molten metal and sends it back to the glass band. This prevents fast cooling of the upper surface layer of the glass melt, which ensures homogenization of temperatures across the glass layer depth. Since heat at high temperatures is mainly transferred by radiation, the use of such screen is quite effective.

Another possibility is the development of more homogeneous temperature conditions inside the melt tank, for which heat pipes (heat exchangers) are used (U.S. patent No. 4092140). The purpose of the heat pipes in this case consist in transferring heat from hotter central zones of the melt tank to the lateral walls.

Another method for controlling the process of glass melt spreading and the cross-section temperature distribution proposes to deliberately arrange tin flows in this zone. It is proposed to place asynchronous linear motors in the glass melt spreading zone immediately after the melt discharge, which develop a flow of tin melt across the tank and thus contribute to homogenization of temperatures across the glass band width (U.S. patent No. 1123222).

To intensify the effect of temperature homogenization across the band width, it is proposed to combine the linear motors with heating devices, i.e., special graphite heaters im-

mersed in the tin melt or installed above the glass band edges (U.S. patent No. 3817735).

There are known solutions, in which the configuration of the discharge unit is modified to improve the discharge and spreading conditions. Thus, the literature describes using a concave chute or a concave proportioning valve, which provides for a higher flow rate at the center (Gr. Britain patent No. 1068345). The development of such profile in the discharge is equivalent to heating the central layers of the melt, in which their viscosity decreases and the flow velocity at the center grows. A similar design of the concave chute is also described in another method for feeding glass melt (USSR Auth. Certif. No. 245282).

A method is known where the flow velocities are controlled due to the valve configuration, whose lower part has a convex shape (U.S. patent No. 3973940). This develops a glass melt flow whose thickness in the middle is smaller than at the edges. Such feed of the glass melt ensures a uniform velocity across the width of the flow.

In another variant the bottom of the melt tank has a depression in the front part, so that the depth of the metal melt in the central part is greater than in the lateral parts (U.S. patent No. 3936289). Since melted metal conducts heat faster than glass melt, it removes more heat from the glass melt in the central part of the tank, where the metal depth is greater, than in the lateral parts, as a consequence of which the temperature gradient of glass across the flow decreases.

The Saratov Institute of Glass is searching for technological and design solutions that can weaken the effect of the negative factors in the discharge and spreading zones on optical parameters of the glass band.

One of these solutions, which is a modification of the configuration of the discharge unit elements, proposes feeding glass melt through a wider chute (RF patent No. 2149838). The advantage of the proposed method is that it enables one to reduce lateral spreading of the glass melt. In this case heat losses in the lateral spreading zone decrease and, accordingly, the temperature gradient across the flow width decreases as well.

A significant feature of the proposed method is that it creates conditions for obtaining high optical parameters not only in standard clear glass, but in heat-shielding glass as well, whose production has to meet stricter requirements on thermal conditions in discharge and molding [7]. The use of a wider chute on the ÉPKS-4000 production line has had a positive effect and made it possible to produce glass with better optical parameters.

Experimental studies and analysis of the technical patent literature demonstrated that the opportunities of improving optical characteristics of glass by improving the conditions of discharge and spreading of glass melt are not yet exhausted. The possibilities and the need for further improvement of the discharge unit has been substantiated, not only for the purpose of improving quality but also for producing glass of different grades, sizes, compositions, and functional purposes.

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